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CELLULOSE.—THE CHOICE OF PAPER FOR BOOKS.

Cellulose: an Outline of the Chemistry of the Structural Elements of Plants with reference to their Natural History and Industrial Uses. By Cross and Bevan. Pp. 320. (London: Longmans, Green, and Co., 1895.)

NO more aggravating book could be placed in the hands of a reviewer: inchoate in the highest degree, it deals with a subject of extraordinary interest and importance in an absolutely original manner; it teems with suggestions which those who can read between the lines will find of the greatest value; but it is disfigured by an obscurity of diction which must materially diminish its usefulness, and to do it justice a degree of patience and long-suffering must be exercised which probably few possess. Certainly it has taken me a long time to screw up my courage to the point of venturing to publicly discuss its merits; but the delay has served a good purpose: had I recorded my first impressions, they would have been highly unfavourable; whereas I can now say that the more often I take the book in hand the more it fascinates me, and the more I realise how important are the problems it presents for consideration. In fact, whatever the faults of the work, all who are in any way concerned with the manifold uses which cellulose subserves, whether in nature or art, must seek to appreciate its contents, and must study it as by far the most important contribution to the subject published since the appearance in 1876 of the magnificent fragment, entitled, "Die Pflanzenfaser und ihre Aufbereitung für die Technik," by Dr. Hugo Müller. A comparison of the two books shows how extraordinary is the progress made during the past twenty years; and yet how absolutely ignorant we remain of the nature of cellulose.

Many may ask, What is cellulose? To which we must reply, We cannot say! It is impossible at present to define it more exactly than as being the main element of the cellular structure of plants; as the structural basis of the vegetable world—to use Messrs. Cross and Bevan's expression, so that its German appellation, cell-stuff, gives in a single word the best definition possible. But whereas formerly we thought of it always in connection with cotton-wool, it is now becoming customary to associate the name with a variety of substances, and to regard cotton-wool cellulose as only the most highly developed term of a series of celluloses

Cellulose belongs to the great secret society we term *carbohydrates*—I say secret, because all but the inferior members are sealed books to us. A carbohydrate is a compound in which carbon is associated with oxygen and hydrogen, these elements being present in the proportions in which they occur in water; an important consideration to be borne in mind when the attempt is made to consistently define a cellulose. For years we lived under the comfortable conviction that the carbohydrates contained, if not six, some integral multiple of six carbon atoms in the molecule, and they were all natural, products; but then it was discovered that ordinary gum arabic affords a carbohydrate containing only five atoms of carbon—*i.e.* the pentose arabinose; and more recently we have learnt to improve on nature, and have shown how vastly greater are our powers by raising the number of hexaldoses isomeric with ordinary honey glucose, $C_6H_{12}O_6$, from three—the number obtained from natural sources—to eleven; the maximum number possible being, we believe, sixteen: a sufficiently wonderful achievement; in fact, probably the greatest feat recorded in the history of chemical discovery, and the more so when we consider that we have not only made them, but have also, we venture to believe, successfully allocated to the atoms in the molecule of each of the forms their relative positions in space. It may be added that we are now acquainted with a complete series of homologous "glucoses" containing from one up to nine carbon atoms, most of them being artificial products.

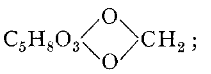
Nature, however, has hitherto baffled us in the case of so well-defined a carbohydrate as ordinary sugar—call it, as we may, either cane or beet sugar, since but one and the same substance is procurable from either source, although many "educated" folk still insist on the contrary. Notwithstanding that we know the size of its molecule, we have not yet precisely determined its structure, which is proof that our analytic powers are after all but very limited, and that there is no relation between cheapness and constructiveness: as if there were, we should long ago have entirely mastered a material tons upon tons of which may be had in an almost pure state at about twopence a pound—in itself a sufficiently noteworthy circumstance; indeed, no other article of commerce illustrates in so striking a manner the perfection attained in modern manufacturing processes. Above cane sugar, higher in the series, all is chaos: of dextrin, glycogen, inulin, starch and the celluloses, &c., we know no more than that in some way they are, with very few exceptions, derived from ordinary glucose; it is generally supposed that their molecules are *highly* complex, but the evidence on this point is by no means complete. Progress is barred by the absence of methods of attacking such problems, and we must patiently await the arrival of the pioneers who will successfully penetrate into regions which we have hitherto always failed in exploring beyond the frontiers. From this point of view, especially, men like Messrs. Cross and Bevan are particularly deserving of encouragement, as they have given clear proof of ability in opening up new lines of inquiry—by far the most valuable office to render at such a juncture.

Cane sugar, $C_{12}H_{22}O_{11}$, and its congeners are with great facility resolved into two hexose molecules by hydrolysis; and all other higher carbohydrates, excepting the celluloses, are without difficulty simplified by the action of dilute mineral acids and a number of enzymes. The behaviour of starch is altogether remarkable: when subjected to the action of an extract of malt, it is very rapidly attacked, even at ordinary temperatures, if previously gelatinised; in the first instance, it is converted into soluble starch, and then into "dextrins" and maltose, the isomeride of cane sugar. This is not the place to enter into any discussion of the various "dextrins," or of the peculiarities which they manifest:

suffice it to say that the subject is still enshrouded in mystery.

Although some, if not all, of the celluloses more or less readily undergo hydrolysis under natural conditions in plants, the difficulty with which cotton cellulose is resolved by acid hydrolysts is surprising in comparison with the readiness with which starch is attacked; and when hydrolysis takes place, the tendency is to form dextrose: in no case has the production of a substance corresponding to that of maltose from starch been observed. How are these and other peculiarities to be explained? At present the only thing clear to us is that although fundamentally both dextrose derivatives, cellulose and starch are seemingly constructed on different types; so that the conversion of one into the other, in whichever direction it may occur, involves a passage through dextrose.

Messrs. Cross and Bevan attach great importance to the formation from cellulose of a large quantity—30 to 35 per cent.—of acetic acid on fusing it with alkali, a behaviour which no other carbohydrate exhibits; to account for this, they assume that cellulose contains the group $CO.CH_2$, and they are inclined to think that this forms part of a closed chain of six carbon atoms constituting the fundamental C_6 group of the carbohydrate; but in the absence of definite evidence, so unconventional a view can only be regarded as a working hypothesis put forward with the object of emphasising the peculiarities of cellulose in comparison with other carbohydrates.

There are, at least, two other types of cellulose which are far more widely distributed in the plant world than is that of the cotton type, viz. those obtained from woods and ligneous tissues generally, and those from cereal straws, esparto, &c.; but such celluloses contain a larger proportion of oxygen, and are in fact *oxycelluloses*—so that, strictly speaking, they are not carbohydrates: they are characterised by yielding more or less furfuraldehyde on distillation with muriatic acid, wood cellulose giving from two to six per cent., and esparto as much as twelve. The ligno-celluloses constitute another class, belonging, however, to the group of compound celluloses, of which there seem to be many varieties; they contain a non-cellulose constituent almost of a benzenoid character. All these are much less resistant than cotton cellulose. In a recent communication to the Chemical Society Messrs. Cross, Bevan, and Smith have shown that it is possible, by a process of regulated hydrolysis, to resolve the cereal straws into a resistant cellulose and a substance which they believe to be a formal-pentose,  $C_5H_8O_3\begin{matrix}O\\ \\O\end{matrix}CH_2$; they regard this as the primary source of the furfural obtained on hydrolysing many celluloses. Furthermore, they find that the substance of this type varies in character with the stage of growth, being completely fermentable at an early stage, but not in the later stages. This discovery marks an important advance in our knowledge, and its development may be looked forward to with the greatest interest.

Finally, it is to be noted that in addition to celluloses primarily derived from ordinary dextrose, others exist in the formation of which isomerides of dextrose have taken part—vegetable ivory, for example, yields instead of dextrose the closely related substance mannose on hydrolysis, mannose differing from dextrose only in the relatively different position of the groups associated with the asymmetric carbon atom next the COH group.

These illustrations will suffice to show how complex a chapter in organic chemistry we have to deal with in considering the celluloses; but it is only in recent times, and in no small measure owing to Messrs. Cross and Bevan's work, that we have been led to appreciate this fact. A perusal of their book will show how, as yet, we have but touched the outermost fringe of the inquiry into their nature, metamorphoses and origin, and how fertile, but at the same time infinitely difficult, a field they present for research.

It is almost impossible to exaggerate the value of a thorough knowledge of all that relates to the celluloses, when we consider the astonishing variety of uses to which they are put, and the importance of the industries in which they constitute the raw material. Thus we not only clothe ourselves largely with cellulose in the form of cotton and linen fabrics, and make from it the paper on which we write and on which we print our books, besides using it for a multitude of other peaceful purposes, but even convert it into guncotton, and from this fashion smokeless powder wherewith to confound our enemies: indeed, no more striking illustration of the revolution in our practices that science is effecting could be given than is afforded by the fact that a material like gunpowder, after being in use during so many centuries, should have been suddenly, almost entirely, displaced by the cellulose nitrates and the closely related nitroglycerin—the glycerin, from which the latter is made, also being obtained largely from vegetable sources as well as from animal fats, and being procurable as a bye-product, in large quantity, because our modern civilisation has imposed upon us the fashion of constantly washing with the aid of soap, which we are impelled to buy by ubiquitous advertisements.

Now that the plastic nature of the celluloses is becoming understood, it is to be expected that they will be made use of in many other equally striking novel ways: the projected manufacture of a substitute for silk through the agency of nitrated cellulose is a case in point.

Messrs. Cross and Bevan have much to say on the quality of paper on which permanent records should be printed—undoubtedly a question of great importance, which has in no way received the attention it deserves. Their book is printed upon a paper carefully selected as composed of "normal" celluloses, to the exclusion of the inferior celluloses ordinarily employed in the manufacture of printing papers; and it certainly affords an agreeable contrast in this respect to the majority of books issued at the present day. Formerly, when paper was made of rags, and china clay was used with a very sparing hand, the material was both strong and little liable to undergo deterioration under ordinary influences—*mais nous avons changé tout cela*. Nowadays not only is a prodigal use made of china clay, but the place of rags is very largely taken by wood and straw. As already pointed out, the celluloses derived from such sources are far less resistant than cotton cellulose; in fact, all papers made from such materials are liable to suffer discolouration under the ordinary conditions of wear and tear, and as they undergo oxidation somewhat readily, they gradually perish and become rotten. Yet, as Messrs. Cross and Bevan point out, in the case of papers used for writing and printing, permanence is a first desideratum :—

> "Books and records have more than a passing value, and it is essential that they should be committed to pages suitably resistant both to chemical and mechanical wear and tear . . . *there is no public opinion in this country upon this important subject.* Where preferences for high-class papers exist, they are based rather upon æsthetic and other recondite considerations than upon any judgment as to composition and the relation of their constituents to the destructive agencies of the natural world. On this basis, while papers admit of a very simple classification into three main groups : (A) Those composed of the normal and resistant celluloses only—*e.g.* cotton, linen ; (B) those composed of celluloses containing oxidised groups or oxycelluloses—*e.g.* wood-cellulose, esparto and straw celluloses ; (C) those containing, in admixture with the above, ground wood or mechanical wood pulps (ligno-cellulose) . . . Class A stands beyond criticism. . . . fibres of Class B have been introduced in response to the enormously increased consumption of paper in this century. . . . their use in books is open to the very obvious objection that the books are more perishable. Of course, it is perfectly true that a large amount of literature is of the ephemeral kind, and in this province such questions as we have raised do not enter ; on the contrary, paper being very much cheapened by the use of these celluloses, a great advantage is gained. It must be insisted upon, however, that authors and publishers should have a definite judgment as to the papers to which they commit their productions, and it would be of the greatest utility to exhaustively investigate these particular celluloses from the point of view of their resistance to the natural processes of decay. Class C : The presence of ligno-cellulose is a more extreme departure from the sound basis of composition represented by Class A . . . papers of this class are only permissible where lasting properties are a question of no moment whatever. . . . The practice of loading papers with china clay . . . is also another of the causes which lead to disintegration of modern papers as compared with those of former days. There is, of course, the other side to this question, the addition of these mineral diluents having certain positive advantages not to be overlooked. The danger of any practices of this kind only enters when they are not measured at their proper utility. *Paper is largely taken for granted by consumers.* In a great many, perhaps the majority of cases, this uninquiring consumption is not attended with any serious consequences ; but, on the other hand, it is quite obvious that it is attended with dangers of a very grave character, when we are dealing with records of value for all time. This, of course, is largely a question for posterity, to whom we are handing down a literature produced upon grounds for the most part of mere commercial expediency. *It is high time, as we have said before, that a public opinion should be formed upon this subject,* and it can only be formed upon a recognised classification of papers, based upon the mechanical and chemical constants, which are determinable by laboratory investigation." (The italics are introduced by me.)

But there is a sunny side to Messrs. Cross and Bevan's disclosures, as they appear to offer a method of overcoming some of the difficulties introduced by the plethora of publications with which we are overwhelmed at the present day, and foreshadow a course of action by which readers of scientific papers might be greatly helped. If we remember that cotton cellulose is unaffected by aniline salts, which colour the oxycelluloses yellow to red, we can imagine what the result might be if all books worth preserving, and just those parts of our scientific papers which are really worth consideration, were printed on sound rag paper. On receipt of a journal, a light wash of aniline solution might be applied to each page : soon afterwards a rosy blush would pervade the greater number, only a few here and there, or those just at the beginning or the end of a paper, retaining their virgin purity of tone : we should at once know what was padding, copied from the note-book to produce an impression of much labour expended and of deep learning ! Works could be avoided by budding authors who in the process of self-education had given birth to compilations to "satisfy wants" felt by themselves alone, and the choice of students restricted to trustworthy sources of information. And the joy of the reviewer would also be great, as he could ascertain what value author and publisher placed on a book, especially if a standard series of tints, corresponding to the several varieties of paper, had been agreed to ; moreover, it would not be necessary to read reviews, and advertisements could be curtailed—as the words "Printed on Class A paper" would serve as a recommendation far better than any garbled "Opinions of the Press." I do not propose to protect the idea, but offer it freely to our Royal and other Societies, although I am aware that a patent is said to be a good advertisement, and the best means of enforcing use. Indeed, I trust that, in making the suggestion, I am but showing that I have derived profit from Messrs. Cross and Bevan's invaluable book, which is most properly printed on Class A paper.

As they truly remark at the close of their work, the chemistry of cellulose

> "is a province of applied chemistry where, as in many others, the distinctions between 'science' and 'practice' exist only in the minds of those who grasp neither the one nor the other. Manufacturers and technical men, if they will only take the trouble to inform themselves, must see that an enormous field of natural products and processes about to be explored has a number of industrial prizes and surprises in store ; scientific men who have to undertake the pioneering work in this field will find sufficient stimulus to effort in the promise of discovery."

H. E. A.

EARLY CHALDEAN CIVILIZATION.

Cuneiform Texts from Babylonian Tablets, &c., in the British Museum. Part I. By L. W. King, M.A. Printed by order of the Trustees. Pp. iv + 50 plates. (Kegan Paul, Longmans, and others, 1896.)

RUMOURS must have reached the general reader from time to time of the "finds" of tablets which have been made by the natives in Southern Babylonia ; and it is a matter for congratulation that, judging by what we see in the volume before us, the results of these "finds" have been acquired by the Trustees of the British Museum. We have long been familiar with tablets of Assyria and Northern Babylonia, and it has long been evident that their contents were taken from clay documents which belonged to a much older period, and were the literary offsprings of a people whose early history had then disappeared in the mists of a remote antiquity. The